



**Description****Field of the Invention**

5 [0001] The invention relates to shaped (non-circular) fiber-reinforced structural members. More particularly, the invention relates to fiber-reinforced structural members having an exterior fiber-reinforced thermoset layer formed on a thermoplastic profile. Such reinforced profiles have a variety of useful cross-sectional shapes having acceptable mechanical strength for high structural loading. The invention also relates to a pultrusion method of forming such a structural member involving an extrusion die for the formation of a thermoplastic profile comprising a thermoplastic composite. The process further involves forming an uncured layer of fiber and thermosetting resin on the profile exterior which can be cured to form the reinforced structural member. The useful shapes of the profile can be complex for specific application in window/door manufacture, automotive, aviation, I. beam and C-channel, and other applications as structural members. Further, the invention also relates to structural units using the fiber-reinforced structural member for increased strength.

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**Background of the Invention**

[0002] A great deal of attention has been directed to the fabrication or manufacture of structural members that can withstand substantial structural loads and varying temperatures arising in the natural environment. In certain arid desert areas, average daily temperatures can reach 38°C (100°F) or more. Most common structural members comprise a support structure using either metallic structures manufactured from aluminum, steel, stainless steel metallic fiber or other high strength metallic material. Further, large structural wooden members have been used in utility poles, bridge components, housing structures and other similar units. Such wooden and metallic structural members have had some substantial success.

20 [0003] Increasing attention has also been given to the manufacture of structural members from thermosetting and thermoplastic materials. Processing these materials offers improved manufacturing properties because of the ease of processing thermosetting and thermoplastic resins and combining those materials with reinforcing fibers.

[0004] Karino et al., U.S. Pat. No. 4,515,737 teach a process for producing a composite circular composite pipe. In the process, a thermoplastic resin pipe is formed using an extruder. The surface of the pipe is covered with a uniform layer comprising continuous fibrous reinforcing material impregnated with a thermosetting resin in its axial direction by a draw molding method, helically winding a continuous fibrous reinforcing material impregnated or not impregnated with a thermosetting resin uniformly on the initial resin fibrous reinforced layer. The Karino et al. material has a polyvinyl chloride pipe center and a first and second fibrous reinforcing layer. This process, using a wrapped layer, cannot be used for complex profile shapes.

25 [0005] Tanaka et al., U.S. Pat. No. 4,740,405 teach an extruded profile or frame member comprising a thermoplastic resin having reinforcing wires throughout the frame member joined using a thermosetting resin. The fibers are typically dispersed within the profile material.

[0006] Balazek et al., U.S. Pat. No. 4,938,823 teach a pultrusion/extrusion method in which continuous transit or longitudinal fiber or roving is coated with a thermosetting resin. The fibers are then combined with one or more fibrous reinforcing mats and pass through a second die to cure the thermosetting resin. This process forms a first profile. The surface of the substantially cured thermoset is then deformed and a thermoplastic resin is then applied to the deformed surface. The deformity in the thermosetting surface provides increased adhesion between the thermoset core and the thermoplastic exterior.

30 [0007] Hirao et al., U.S. Pat. No. 5,030,408 teach a method of forming a molded resin article combining both thermoplastic and thermosetting resins in a kneader extruder to form the article. The structures manufactured by agglomerating thermoplastic materials having a particle diameter of 0.05-0.5 µm with particles of 10-1000 µm diameter prior to kneading, then introducing the thermoplastic material into the kneader.

35 [0008] Strachan, U.S. Pat. No. 5,120,380 teaches a method of forming extruded profiles. In the process, cloth, preferably woven fiberglass is delivered by supply rolls and guided over the external profiled surface of a forming duct. The cloth is maintained in a shape by an air stream provided by a venturi blower. The air stream blows towards the die and at least partially diffuses through the cloth prior to the resin curing die. The air shaped cloth runs into a curing die where it is impregnated with a thermosetting resin. The thermosetting resin is cured into an extruded profile which is then withdrawn from the curing station using a pultrusion tractor device. The prior art shows a variety of thermoplastic / thermosetting composite materials that can be used as structural members. No one structure or method appears to be superior in forming structural members that can resist high structural loads in the varying temperatures found in the natural environment. Substantial need exists for improving the heat distortion temperature of composite structures.

40 [0009] WO91/00466 teaches an extruded thermoplastic synthetic material interior layer and protruded or pull wound thermoplastic outer layer to form a circular cross sectioned plastic pipe. Whilst fibers or fabrics in the outer layer are

The resin and fiber can also be passed through a calibration die to shape the resin and fiber prior to and during curing to regulate and fix the exterior dimensions of the structural member. In a preferred pultrusion method of the invention, a tractor device can be installed after the shaping and cooling die to pull the extruded thermoplastic linear member from the extrusion die through the cooling and sizing device. The pultrusion tractor device can be installed after the 5 curing station forming the thermosetting fiber reinforced layer. Preferably, the process is run using a tractor to pull the completed reinforced member from the curing die. This tractor can be sized to provide all force needed to produce the part.

[0018] In certain applications where stress is typically directed onto the member in a specific or defined stress load direction, the fiber reinforcement can be applied only to an area of the profile positioned to support the entire directional 10 load of the stress. Alternatively, the entire surface of the profile can be covered with fiber reinforcement.

#### Exterior Layer Comprising a Fiber-Reinforced Thermoset

[0019] In the structural members of the application, an exterior layer is formed on the thermoplastic core comprising 15 a fiber-reinforced thermoset. Such an exterior layer is formed using a thermosetting resin. A variety of thermosetting resins are known for use in such applications. Such thermosetting resins include unsaturated polyester resins, phenolic resins, epoxy resins, high-performance epoxy resins, bismaleimides including modified bismaleimides such as epoxy modifications, biscyanate modifications, rubber-toughened bismaleimides, thermoplastic-toughened bismaleimides, and others. In the practice of this invention, the preferred resins comprise unsaturated polyester resins, phenolic resins 20 and epoxy resins.

[0020] Polyester resins are manufactured by the reaction of a dibasic acid with a glycol. Dibasic acids used in polyester production are phthalic anhydride, isophthalic acid, maleic acid and adipic acid. The phthalic acid provides stiffness, hardness and temperature resistance; maleic acid provides vinyl saturation to accommodate free radical cure; and adipic acid provides flexibility and ductility to the cured resin. Commonly used glycols are propylene glycol 25 which reduces crystalline tendencies and improves solubility in styrene. Ethylene glycol and diethylene glycol reduce crystallization tendencies. The diacids and glycols are condensed eliminating water and are then dissolved in a vinyl monomer to a suitable viscosity. Vinyl monomers include styrene, vinyltoluene, paramethylstyrene, methylmethacrylate, and diallyl phthalate. The addition of a polymerization initiator, such as hydroquinone, tertiary butylcatechol or phenothiazine extends the shelf life of the uncured polyester resin. Resins based on phthalic anhydride are termed 30 orthophthalic polyesters and resins based on isophthalic acid are termed isophthalic polyesters. The viscosity of the unsaturated polyester resin can be tailored to an application. Low viscosity is important in the fabrication of fiber-reinforced composites to ensure good wetting and subsequent high adhesion of the reinforcing layer to the underlying substrate. Poor wetting can result in large losses of mechanical properties. Typically, polyesters are manufactured with a styrene concentration or other monomer concentration producing resin having an uncured viscosity of 200-1,000 35 mPa.s(cP). Specialty resins may have a viscosity that ranges from about 20 cP to 2,000 cP. Unsaturated polyester resins are typically cured by free radical initiators commonly produced using peroxide materials. A wide variety of peroxide initiators are available and are commonly used. The peroxide initiators thermally decompose forming free radical initiating species.

[0021] Phenolic resins can also be used in the manufacture of the structural members of the invention. Phenolic 40 resins typically comprise a phenol-formaldehyde resin. Such resins are inherently fire resistant, heat resistant and are low in cost. Phenolic resins are typically formulated by blending phenol and less than a stoichiometric amount of formaldehyde. These materials are condensed with an acid catalyst resulting in a thermoplastic intermediate resin called NOVOLAK. These resins are oligomeric species terminated by phenolic groups. In the presence of a curing agent and optional heat, the oligomeric species cure to form a very high molecular weight thermoset resin. Curing agents for 45 novolaks are typically aldehyde compounds or methylene (-CH<sub>2</sub>-) donors. Aldehydic curing agents include paraformaldehyde, hexamethylenetetraamine, formaldehyde, propionaldehyde, glyoxal and hexamethylmethoxy melamine.

[0022] Epoxy resins are also used in forming thermoset-reinforcing layers. Typical epoxy resin systems are based 50 on an oxirane reaction with an active hydrogen. Epoxy resins are generally characterized as oligomeric materials that contain one or more epoxy (oxirane) groups per molecule. The value of epoxy resins relates to their ease of processing into a variety of useful products or shapes including coatings, structural components of a variety of shape and size. Epoxy groups in the resin are cured with an appropriate curing agent, typically an amine. A variety of commercially 55 available epoxy resins based on phenol, bisphenol, aromatic diacids, aromatic polyamines and others are well known. Specific examples of available commercial resins include a phenolic novolak epoxy resin, glycidated polybasic acid, glycidated polyamine (N, N, N', N'-tetraglycidyl-4,4'-diamino diphenol methane) and glycidated bisphenol A oligomers. Epoxy resins are cured into useful products using curing or cross linking chemical agents. Two principal classes of curing agents used in epoxy resins for advanced composite materials are aromatic diamines and acid anhydrides. Such materials include M-phenylenediamine; 4,4'-methylene dianiline; 4,4'-diaminodiphenyl sulfone; Nadic Methyl Anhydride; hexahydrophthalic anhydride; methyltetrahydrophthalic anhydride and others.

[0023] Fiber-reinforcing materials that can be used in the structural members of the invention typically include high strength fibers such as carbon fibers, glass fibers, aramid fibers, steel fibers, boron fibers, silicon carbide fibers, polyethylene fibers, polyimide fibers and others. Such fibers can be used in the form a single filament, a multifilament thread, a yarn, a roving, a non-woven fabric or a woven fabric material. The fiber, roving, yarn or fabric can be applied linearly along the profile or wrapped, or otherwise formed on the profile in an appropriate pattern that can be cured to form the reinforcing structure.

[0024] 5 Strachan, U.S. Patent No. 5,120,380, teaches an in-line manufacture of fiber filled pultruded profiles. The Strachan technology involves forming hollow profiles using a long heated mandrel which can be filled with foam. Strachan uses a driven air blast to maintain a hollow uncured member to prevent collapse of the profile and to maintain its shape during curing. This process is slow, requires long support mandrels shaped to the required hollow profile and limits the practicality of producing some profiles at economical rates.

[0025] 10 The process of the Invention uses a continuously extruded and cooled profile as a mandrel upon which resin and fiber or strips of reinforced media are applied to the mandrel/extrudate. The use of the extrudate as a mandrel substantially increases throughput, provides an accurate gauge of sizing rapid economical throughput. Further, the process allows for greater thickness range of the resulting structural member, increased production rates, flexibility in placement of reinforcing materials, thermally or vibrationally weldable profiles, permits the inclusion of "foamed-in-place" areas to facilitate screw, nail or other fastener retention, has added strength over other reinforced media due to a synergistic bonding between the core and the reinforcing layer. The characteristics of the preferred thermoplastic fiber composite core highlighted in the improved physical properties including a high heat distortion temperature (HDT) 15 in excess of 100°C, a Young's modulus or specific modulus in excess of 3450MPa (500,000 psi) preferably greater than 6900MPa (1,000,000 psi) and an elongation at break of less than 3% and commonly between 1 and 3%, a tensile strength of greater than 45MPa (6,500 psi).

#### Method

[0026] 20 Figure 1 shows the general method. Pellets of FIBREX™ a PVC/wood fiber composite of about 60 parts PVC and 40 parts wood fiber are fed into an extruder (1) via the extruder throat (2). The pellets are heated, mixed and compressed in the extruder barrel (3), and then pushed via the extruder screw (4) through an adapter (5) and then a shaped die (6). On exiting the die, the profile (7) is pulled by a puller (8) through a series of vacuum sizers (9) or vacuum box (10) with integral sizing plates (11). The vacuum sizers (9) and/or vacuum box (10) spray water (19) onto the profile to reduce its temperature to below the H.D.T. of FIBREX™. This temperature is not to be construed as critical since those familiar with the art will recognize temperature variations as being part of the running process truly relevant to each profile.

[0027] 25 From the profile puller (8) the profile (7) is fed through a pultrusion die (20).

[0028] 30 At the same time, continuous strands of fiber (13) are soaked in a thermoset resin by being pulled through a wetting bath (21) and then through the pultrusion die (20). This process forms a bond between the FIBREX™ center mandrel and the reinforced thermoset resin.

[0029] 35 Those familiar with the art will recognize the possibility of substituting woven cloth for strands should the profile design so require it.

[0030] 40 Prior to entering the die (20) the resin wetted fibers are subjected to heating by - but not limited to - R.F. waves (12) to facilitate curing. Upon exiting the pultrusion die (20) the profile is fully shaped and cured. Dies (20 & 6) are heated and such heats are controlled to produce the desired profiles and affect the rate of production.

[0031] 45 The cured profile is pulled from the pultrusion die by a second puller (17) and then cut to length (18).

[0032] 50 Fig. 2 shows a cross-section of a structural member of the invention. The structural member includes a fiber reinforced thermoplastic layer 21 covered by a fiber reinforced thermosetting layer 20. The thickness of these layers typically ranges from about 0.25cm (0.1 inches) to about 0.76cm (0.3 inches). The structural member is in the form of a relatively complex profile shape, generally rectangular, having dimensions of about 2.5-7.6cm x 5-10cm (1-3 inches x 2-4 inches). The core fiber reinforced thermoplastic mandrel shape has a complex structure 23 which represents a variety of complex shapes that can be introduced into a load bearing structural member. The fiber reinforced thermosetting layer 20 is introduced into a channel in the fiber reinforced thermoplastic layer. The material is fully contacted with the interior of channel 23 without the formation of any substantial bubbles or voids. Such complex shapes can add to both the utility of a structural member in a particular application or can add structural engineering properties to the overall member.

[0033] 55 The structural members of this invention are fiber-thermoset reinforced polymer and wood fiber extrusions having a useful cross-sectional shape that can be adapted to any structural application in construction of buildings, cars, airplanes, bridges, utility poles, etc. The members can be used in window or door construction and the installation of useful window components or parts into the structural member. The structural member can be an extrusion in the form or shape of rail, jamb, stile, sill, track, stop or sash. Additionally, non-structural trim elements such as grid, cove,

quarter-round, etc., can be made. The extruded or injection molded structural member comprises a hollow cross-section having a rigid exterior shell, or wall, at least one internal structural or support web and at least one internal structural fastener anchor. The shell, web and anchor in cooperation have sufficient strength to permit the structural member to withstand normal wear and tear related to the operation of the window or door. Fasteners can be used to assemble the window or door unit. The fasteners must remain secure during window life to survive as a structural member or component of the residential or commercial architecture. We have further found that the structural members of the invention can be joined by fusing mating surfaces formed in the structural member at elevated temperature to form a welded joint having superior strength and rigidity when compared to prior art wooden members.

5 [0034] The interior of the structural member is commonly provided with one or more internal structural webs which in a direction of applied stress supports the structure. Structural web typically comprises a wall, post, support member, or other formed structural element which increases compressive strength, torsion strength, or other structural or mechanical property. Such structural web connects the adjacent or opposing surfaces of the interior of the structural member. More than one structural web can be placed to carry stress from surface to surface at the locations of the application of stress to protect the structural member from crushing, torsional failure or general breakage. Typically, 10 such support webs are extruded or injection molded during the manufacture of the structural material. However, a support can be post added from parts made during separate manufacturing operations.

15 [0035] The internal space of the structural member can also contain a fastener anchor or fastener installation support. Such an anchor or support means provides a locus for the introduction of a screw, nail, bolt or other fastener used in either assembling the unit or anchoring the unit to a rough opening in the commercial or residential structure. The 20 anchor web typically is conformed to adapt itself to the geometry of the anchor and can simply comprise an angular opening in a formed composite structure, can comprise opposing surfaces having a gap or valley approximately equal to the screw thickness, can be geometrically formed to match a key or other lock mechanism, or can take the form of any commonly available automatic fastener means available to the window manufacturer from fastener or anchor parts manufactured by companies such as Amerock Corp., Illinois Tool Works and others.

25 [0036] The structural member of the invention can have premolded paths or paths machined into the molded thermoplastic composite for passage of door or window units, fasteners such as screws, nails, etc. Such paths can be counter sunk, metal lined, or otherwise adapted to the geometry or the composition of the fastener materials. The structural member can have mating surfaces premolded in order to provide rapid assembly with other window components of similar or different compositions having similarly adapted mating surfaces. Further, the structural member can 30 have mating surfaces formed in the shell of the structural member adapted to moveable window sash or door sash or other moveable parts used in window operations.

[0037] The structural member of the invention can have a mating surface adapted for the attachment of the weigh subfloor or base, framing studs or side molding or beam, top portion of the structural member to the rough opening. Such a mating surface can be flat or can have a geometry designed to permit easy installation, sufficient support and 35 attachment to the rough opening. The structural member shell can have other surfaces adapted to an exterior trim and interior mating with wood trim pieces and other surfaces formed into the exposed sides of the structural member adapted to the installation of metal runners, wood trim parts, door runner supports, or other metal, plastic, or wood members commonly used in the assembly of windows and doors.

[0038] Using extrusion methods a pellet and extruding the pellet into a structural member, an extruded piece as 40 shown in Fig 2, extrusion 20 was manufactured. The wall thickness of any of the elements of the extrudate was about 0.42cm (0.165 inches).

A Cincinnati Millicon extruder with an HP barrel, a Cincinnati pelletizer screws, and AEG K-20 pelletizing head with 45 260 holes, each hole having a diameter of about 0.51mm (0.0200 inches) was used to make a pellet. The input to the pelletizer comprise approximately 60 wt-% polymer and 40 wt-% sawdust. The polymer material comprises a thermoplastic mixture of approximately 100 parts of vinyl chloride homopolymer, about 15 parts titanium dioxide, about 2 parts ethylene-bis-stearimide wax lubricant, about 1.5 parts calcium stearate, about 7.5 parts Rohm & Haas 980-T acrylic resin Impact modifier/process aid and about 2 parts of dimethyl tin thioglycolate. The sawdust input comprises a wood fiber particle containing about 5 wt-% recycled polyvinyl chloride having a composition substantially identical to the polyvinyl chloride recited above. The initial melt temperature of the extruder was maintained between 375°C and 425°C. 50 The pelletizer was operated on a vinyl/sawdust combined ratio through put of about 360kg/hr (800 pounds/hour). In the initial extruder feed zone, the barrel temperature was maintained between 215-225°C. In the intake zone, the barrel was maintained at 215-225°C, and the compression zone was maintained at between 205-215°C and in the melt zone the temperature was maintained at 195-205°C. The die was divided into three zones, the first zone at 185-195°C, the second zone at 185-195°C and in the final die zone 195-205°C. The pelletizing head was operated at a setting providing 55 100-300 rpm resulting in a pellet with a diameter of about 5 mm and a length as shown in the following Table.

[0039] In a similar fashion the core extruded from a vinyl wood composite pellet using an extruder within an appropriate extruder die. The melt temperature of the input to the machine was 199-216°C (390-420°F). A vacuum was pulled on the melt mass of no less than 3 inches mercury. The melt temperatures through the extruder was maintained

at the following temperature settings:

5	Barrel Zone No. 1 - 220-230°C
	Barrel Zone No. 2 - 220-230°C
	Barrel Zone No. 3 - 215-225°C
	Barrel Zone No. 4 - 200-210°C
10	Barrel Zone No. 5 - 185-195°C
	Die Zone No. 6 - 175-185°C
	Die Zone No. 7 - 175-185°C
	Die Zone No. 8 - 175-185°C

The screw heater oil stream was maintained at 180-190°C. the material was extruded at a line speed maintained between 1.5 and 2.1m/min (5 and 7 ft./min).

<b>EXPERIMENTAL</b>	
<b>SHOP ORDER:</b>	
<b>MATERIAL QUANTITIES:</b>	
DESCRIPTION	QUANTITY
PSII beam section (rectangular profile about 5 x 10 cm (2 inches x 4 inches) - 4mm thickness (0.16 inch thickness)	length >38cm (15")
1522. E-glass plain weave fabric	19 plies @ -38 x 30cm (15" x 12") (38cm (15") dimension along warp) 3 plies @ - 40 x 33cm (16" x 13") (orient for best nesting)
Ashland Aropol 7240 T 15 room temperature cure polyester resin	225 grams
MEKP-9 catalyst	3 grams
perforated release film	1 piece @ 40 x 33cm (16" x 13")
non-perforated release film	1 piece @ 40 x 35cm (16" x 14")
felt breather	1 piece @ 51 x 66cm (20" x 26")
bagging film	1 piece @ 66 x 76cm (26" x 30")
bag sealant tape	1.4m (~56")
sheet metal caul plates	2 @ 10 x 30cm (4" x 12") 2 @ 5 x 30cm (2" x 12")

**PREPARATION OF MATERIALS:**

[0040]

55	1-1. Lightly sand surface of PSII beam section with 180 grit sandpaper. With clean cloth and/or air clean off dust from sanding.
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(continued)

	1-2.	Cut plies of E-glass cloth and pieces of perforated release film, non-perforated release film, breather, and bagging fin to dimensions given in "MATERIAL QUANTITIES". Cut sheet metal caul plates and remove any burrs or sharp edges.
5	1-3.	Dry fit the E-glass cloth and process materials around the PSII beam.
10	1-4.	Cut two holes in the bagging film for two ports, one for the vacuum source and one for the gauge to measure vacuum pressure. The two vacuum ports should be located off of the PSII beam.
15	1-5.	Lay down the bag sealant tape along the perimeter of approximately one half of the bag. Do not remove the film from the sealant tape.
20	1-6.	Locate the two ports in the vacuum bag.
25	1-7.	Lay down a piece of plastic film on a flat surface where wetting-out of the plies will occur.
	1-8.	Weigh out polyester resin in plastic container. Weigh out catalyst in a graduated cylinder. Add the catalyst to the resin and mix thoroughly.

25 LAY-UP PROCESS:

	[0041]	2-1.	With PSII beam in holding fixture, brush a coat of resin on the PSII beam.
30		2-2.	On the piece of plastic film brush the resin on one 38cm x 30cm (15" x 12") ply of E-glass cloth.
		2-3.	Wrap the ply all the way around the PSII beam. Squeegee (from the center toward the edges) the cloth to remove any entrapped air.
35		2-4.	Repeat steps 2-2 and 2-3 until all 19 plies are applied to the PSII beam. The overlap or butt joint of each ply should be offset from the previous ply approximately 1.3cm (0.5").

40 VACUUM BAGGING AND CURE:

	[0042]	3-1.	Wrap the perforated release film around the PSII/E-glass/polyester (hybrid) beam.
45		3-2.	Wrap the three 40cm x 33cm (16" x 13") plies of E-glass cloth (bleeder) around the perforated release film.
		3-3.	Wrap the non-perforated release film around the bleeder.
50		3-4.	Locate the four caul plates on each of the four faces of the beam and hold in place with tape.
		3-5.	Wrap the breather around the caul plates.
55		3-6.	Remove the film from the bag sealant tape. Wrap the bagging film around the breather and squeeze the bag sealant tape to seal the bag.
		3-7.	Connect the vacuum source and draw vacuum. Check for leaks in vacuum bag and seal.

(continued)

3-8.	Cure at room temperature for 16 hours minimum.
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5 [0043] Flexural testing was conducted according to the generic specifications set forth by ASTM D-790. The span length was 1.5m (60 inches); loading rate was 0.90cm/min (.35in/min). Load versus displacement slopes were measured using an Instron 4505. In this manner, the load versus displacement slope, m, of the composite beam was measured to be 229 kg/cm (1278 lb/in).

10 [0044] Beam theory predicts the load slope, m, to be:

$$M = \frac{48EI}{L^3} \quad \text{Equation 1}$$

15 wherein:

E = the beam material flexural modulus, psi

I = moment of inertia of the beam, in<sup>4</sup>

L = beam span length between supports, in

20 [0045] Flexural modulus values of FIBREX™ and the fiberglass reinforced polyester (FRP) material prepared, as described, were measured in separate, independent experiments. These values were found to be 5100MPa (740,000 psi) and 13,800MPa (2,000,000 psi) respectively. The moments of inertia of the FIBREX™ and FRP layers (See Fig. 2) in this example are 52.00cm<sup>4</sup> (1.273 in<sup>4</sup>) and 86.28cm<sup>4</sup> (2.073 in<sup>4</sup>) respectively.

25 [0046] If there was no interaction between the two material layers, one would expect the load slope contribution from each to be additive:

$$\begin{aligned} M_{\text{total}} &= M_{\text{FIBREX}} + M_{\text{FRP}} \\ 30 &= \frac{48(740,000)(1.273)}{(60)(60)(60)} + \frac{48(2,000,000)(2,073)}{(60)(60)(60)} \\ &= 209 + 921 \\ &= 202 \text{kg/cm (1130lb/in)} \quad \text{Equation 2} \end{aligned}$$

35 [0047] The difference between the predicted load slope 202kg/cm (1130lb/in) and the measured load slope 229kg/cm (12781b/in) demonstrates an interaction between the composite layers.

40 [0048] Testing the adhesive bond in shear between the FIBREX™ and the fibreglass reinforced polyester (FRP) was completed according to ASTM D-3163. The crosshead speed used was 0.43cm/min (0.17 in/min) and the bond area was 1.6cm<sup>2</sup> (0.25 in<sup>2</sup>). Loads in excess of 204kg (4501bs) were applied to the bond. The corresponding minimum shear strength was calculated as follows:

$$45 t = \frac{P}{A}$$

where

P = max load (lb)

A - bond area (in<sup>2</sup>)

$$t = \frac{204 \text{kg (450.0lb)}}{1.6 \text{cm}^2 (0.25 \text{in}^2)} = 12.4 \text{MPa (1800 psi)}$$

50 [0049] The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the scope of the invention, the invention resides in the claims hereinafter appended.

**Claims**

1. A composite structural member (23) having a core (21) and an intimately bonded exterior layer (20), said member comprising:

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- (a) a thermoplastic linear extruded core (21) comprising a polymer composite composition comprising a fiber reinforced polyvinyl chloride; and
- (b) an exterior layer (20) comprising a fiber-reinforced thermoset; wherein the core (21) is a non-circular profile shape.

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2. The member (23) of claim 1 wherein the core (21) comprises a linear extrudate having a hollow square or hollow rectangle cross section with a wall thickness greater than 1 mm.

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3. The member (23) of claim 1 or claim 2 wherein the exterior layer(20)covers the entire surface of the linear core (21).

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4. The member (23) of any of claims 1 to 3 wherein the exterior layer (20) is placed on the core (21) to provide reinforcement in a defined direction of applied stress.

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5. The member (23) of any of claims 1 to 4 wherein the core comprises an extruded thermoplastic composite comprising a major proportion of polyvinyl chloride and a minor proportion of a reinforcing cellulosic fiber.

6. The member (23) of claim 5 wherein the cellulosic fiber is present at a concentration of about 15 to 40 wt-% of the core (21).

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7. The member (23) of claim 5 or claim 6 wherein the cellulosic fiber is a wood fiber with a particle size of about 0.3 mm to 10 mm and an aspect ratio of about 1 to 10.

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8. The member (23) of claim 5 or claim 6 wherein the cellulosic fiber is a wood fiber with a length of about 0.3 mm to 3 mm and a width of 0.1 mm to 3 mm and an aspect ratio of about 2 to 7.

9. The member (23) of any of claims 1 to 8 wherein the thermoset comprises an unsaturated polyester resin.

10. The member (23) of any of claims 1 to 9 wherein the fiber of the exterior layer (20) comprises glass fiber.

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11. The member (23) of any of claims 1 to 10 wherein there is about 20 to 40 wt-% of thermoset resin and about 80 to 60 wt-% of glass fiber in the exterior layer (20).

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12. A method of manufacturing a pultruded composite structural member (23) having a thermoplastic core (21) and bonded to the core (21) an exterior layer (20) comprising a fiber-reinforced thermoset, the method comprising the steps of:

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(a) extruding a thermoplastic composition comprising polyvinyl and fiber reinforcement through an extrusion die station having a defined non-circular cross-sectional profile to form a linear core profile extrudate at an elevated temperature;

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(b) calibrating the dimensions of the core profile extrudate and cooling the extrudate to form a profile 7 with fixed dimensions;

(c) forming an uncured exterior layer comprising fiber and an uncured thermosetting resin on the cooled profile with fixed dimension; and

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(d) curing the exterior layer to form a structure member 23 comprising a thermoplastic fibre reinforced composite core and a reinforcing fiber reinforced thermoset exterior layer.

13. The process of claim 12 wherein the exterior layer (20) is applied to the profile in the form of a wrapped roving.

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14. The process of claim 12 or claim 13 wherein the exterior layer (20) is combined with uncured resin prior to application to the profile.

15. The process of any of claims 12 to 14 wherein a tractor device provides linear motion to the profile (7) through the process wherein the tractor device (8) contacts the structural member (23) is cured.

16. The process of claim 15 wherein the additional tractor devices (17) are installed after the profile with fixed dimension.
- 5 17. The process of any of claims 12 to 16 wherein the core (21) comprises a linear extrudate having a hollow square or hollow rectangular cross section with a wall thickness greater than 1 mm.
- 10 18. The process of any of claims 12 to 17 wherein the exterior layer (20) covers the entire surface of the core (21).
19. The process of any of claims 12 to 18 wherein the exterior layer (20) is placed on the core (21) to provide reinforcement in a defined direction of applied stress.
- 10 20. The process of any of claims 12 to 19 wherein the core (21) comprises a thermoplastic composite comprising a major proportion of polyvinyl chloride and a minor proportion of a cellulosic fiber.
- 15 21. The process of claim 20 wherein the cellulosic fiber is present at a concentration of about 15 to 40 wt-% of the core.
22. The process of claim 20 or claim 21 wherein the cellulosic fiber is a wood fiber with a particle size of about 0.3 mm to 10 mm and an aspect ratio of about 1 to 10.
- 20 23. The process of claim 20 or claim 21 wherein the cellulosic fiber is a wood fiber with a length of about 0.3 mm to 3 mm, a width of about 0.01 to 3 mm and an aspect ratio of 2 to 7.
24. The process of any of claims 12 to 23 wherein the thermoset comprises an unsaturated polyester resin.
- 25 25. The process of any of claims 12 to 24 wherein the fiber of the exterior layer 20 comprises glass fiber.
26. The process of any of claims 12 to 25 wherein the exterior layer 20 comprises about 20 to 40 wt-% of thermoset resin and about 80 to 60 wt-% of glass fiber.

30

#### Patentansprüche

1. Verbundbauelement (23), das einen Kern (21) und eine damit innig verbundene äußere Schicht (20) hat, wobei das Element folgendes aufweist:
  - (a) einen thermoplastischen linearen extrudierten Kern (21), der ein Polymerverbundgemisch aufweist, das ein faserverstärktes Polyvinylchlorid aufweist; und
  - (b) eine äußere Schicht (20), die einen faserverstärkten Duroplast aufweist; wobei der Kern (21) eine Gestalt mit nichtkreisförmigem Profil ist.
2. Element (23) nach Anspruch 1, wobei der Kern (21) ein lineares Extrudat aufweist, das einen hohen quadratischen oder hohen rechteckigen Querschnitt mit einer Wandstärke von mehr als 1 mm hat.
- 45 3. Element (23) nach Anspruch 1 oder Anspruch 2, wobei die äußere Schicht (20) die Gesamtoberfläche des linearen Kerns (21) bedeckt.
4. Element (23) nach einem der Ansprüche 1 bis 3, wobei die äußere Schicht (20) auf dem Kern (21) angebracht ist, um eine Verstärkung in einer definierten Richtung einer aufgebrachten Beanspruchung zu bilden.
- 50 5. Element (23) nach einem der Ansprüche 1 bis 4, wobei der Kern einen extrudierten Thermoplastverbundwerkstoff aufweist, welcher einen Hauptanteil Polyvinylchlorid und einen kleinen Anteil einer Cellulose-Verstärkungsfaser aufweist.
- 55 6. Element (23) nach Anspruch 5, wobei die Cellulosefaser in einer Konzentration von ungefähr 15 bis 40 Gew.-% des Kerns (21) anwesend ist.
7. Element (23) nach Anspruch 5 oder 6, wobei die Cellulosefaser eine Holzfaser mit einer Teilchengröße von unge-

fähr 0,3 mm bis 10 mm und einem Seitenverhältnis von ungefähr 1 bis 10 ist.

8. Element (23) nach Anspruch 5 oder 6, wobei die Cellulosefaser eine Holzfaser mit einer Länge von ungefähr 0,3 mm bis 3 mm und einer Breite von 0,1 mm bis 3 mm und einem Seitenverhältnis von ungefähr 2 bis 7 ist.
- 5 9. Element (23) nach einem der Ansprüche 1 bis 8, wobei der Duroplast ein ungesättigtes Polyesterharz aufweist.
10. Element (23) nach einem der Ansprüche 1 bis 9, wobei die Faser der äußeren Schicht (20) eine Glasfaser aufweist.
- 10 11. Element (23) nach einem der Ansprüche 1 bis 10, wobei in der äußeren Schicht (20) ungefähr 20 bis 40 Gew.-% Duroplast und ungefähr 80 bis 60 Gew.-% Glasfaser vorhanden sind.
- 15 12. Ein Verfahren zum Herstellen eines stranggezogenen Verbundbauelements (23) mit einem Thermoplastkern (21) und mit einem mit dem Kern (21) verbundenen äußeren Schicht (20), welches einen faserverstärkten Duroplast aufweist, wobei das Verfahren die folgenden Schritte umfaßt:
  - (a) Extrudieren eines Thermoplastgemischs, das Polyvinyl und eine Faserverstärkung aufweist, durch eine Spritzdüsenstation, die ein definiertes nichtkreisförmiges Querschnittsprofil hat, um ein lineares Kernprofilextrudat bei einer erhöhten Temperatur zu formen;
  - 20 (b) Kalibrieren der Abmessungen des Kernprofilextrudats und Abkühlen des Extrudats, um ein Profil (7) mit festgelegten Abmessungen zu formen;
  - (c) Formen einer ungehärteten äußeren Schicht, die Fasern und ein ungehärtetes Duroplastharz aufweist, auf dem abgekühlten Profil mit festgelegter Abmessung; und
  - (d) Aushärten der äußeren Schicht zur Bildung eines Bauelements (23), das einen faserverstärkten Thermoplastgemischkern und eine faserverstärkte äußere Duroplastverstärkungsschicht aufweist.
- 30 13. Verfahren nach Anspruch 12, wobei die äußere Schicht (20) auf das Profil in Form eines gewickelten Rovings aufgebracht wird.
14. Verfahren nach Anspruch 12 oder 13, wobei die äußere Schicht (20) vor dem Aufbringen auf das Profil mit unausgehärtetem Harz kombiniert wird.
- 35 15. Verfahren nach einem der Ansprüche 12 bis 14, wobei eine Zieheinrichtung dem Profil (7) eine Linearbewegung durch den Prozeß hindurch erteilt, wobei die Zieheinrichtung (8) mit dem ausgehärteten Bauelement (23) in Berührung gelangt.
- 40 16. Verfahren nach Anspruch 15, wobei die zusätzlichen Zieheinrichtungen (17) dem Profil mit festgelegten Dimensionen nachgeschaltet sind.
17. Verfahren nach einem der Ansprüche 12 bis 16, wobei der Kern (21) ein lineares Extrudat mit einem hohlen quadratischen oder hohlen rechteckigen Querschnitt bei einer Wandstärke von mehr als 1 mm aufweist.
- 45 18. Verfahren nach einem der Ansprüche 12 bis 17, wobei die äußere Schicht (20) die Gesamtoberfläche des Kerns (21) bedeckt.
19. Verfahren nach einem der Ansprüche 12 bis 18, wobei die äußere Schicht (20) auf dem Kern (21) angeordnet wird, um eine Verstärkung in einer definierten Richtung einer angreifenden Beanspruchung zu bilden.
- 50 20. Verfahren nach einem der Ansprüche 12 bis 19, wobei der Kern (21) ein Thermoplastgemisch aufweist, das einen Hauptanteil Polyvinylchlorid und einen kleinen Anteil einer Cellulosefaser aufweist.
- 55 21. Verfahren nach Anspruch 20, wobei die Cellulosefaser in einer Konzentration von ungefähr 15 bis 40 Gew.-% des Kerns anwesend ist.
22. Verfahren nach Anspruch 20 oder 21, wobei die Cellulosefaser eine Holzfaser mit einer Teilchengröße von ungefähr

0,3 mm bis 10 mm und einem Seitenverhältnis von ungefähr 1 bis 10 ist.

23. Verfahren nach Anspruch 20 oder 21, wobei die Cellulosefaser eine Holzfaser mit einer Länge von ungefähr 0,3 mm bis 3 mm, einer Breite von ungefähr 0,01 bis 3 mm und einem Seitenverhältnis von 2 bis 7 ist.
- 5 24. Verfahren nach einem der Ansprüche 12 bis 23, wobei der Duroplast ein ungesättigtes Polyesterharz aufweist.
25. Verfahren nach einem der Ansprüche 12 bis 24, wobei die Faser der äußeren Schicht (20) eine Glasfaser aufweist.
- 10 26. Verfahren nach einem der Ansprüche 12 bis 25, wobei die äußere Schicht (20) ungefähr 20 bis 40 Gew.-% Duroplastharz und ungefähr 80 bis 60 Gew.-% Glasfaser aufweist.

#### Revendications

- 15 1. Elément de structure composite (23) ayant un noyau (21) et une couche extérieure (20) intimement liée à celui-ci, ledit élément comprenant :
  - (a) un noyau extrudé linéaire thermoplastique (21) comprenant une composition composite polymère comprenant un polychlorure de vinyle renforcé par des fibres ; et
  - (b) une couche extérieure (20) comprenant un thermodurci renforcé par des fibres ; dans lequel le noyau (21) a une forme de profil non circulaire.
- 20 2. Elément (23) selon la revendication 1, dans lequel le noyau (21) comprend un extrudat linéaire ayant une section transversale carrée creuse ou rectangulaire creuse avec une épaisseur de paroi supérieure à 1 mm.
- 25 3. Elément (23) selon la revendication 1 ou la revendication 3, dans lequel la couche extérieure (20) couvre toute la surface du noyau linéaire (21).
- 30 4. Elément (23) selon l'une quelconque des revendications 1 à 3, dans lequel la couche extérieure (20) est placée sur le noyau (21) pour conférer un renfort dans une direction définie de contrainte appliquée.
- 35 5. Elément (23) selon l'une quelconque des revendications 1 à 4, dans lequel la noyau comprend un composite thermoplastique extrudé comprenant une grande proportion de polychlorure de vinyle et une faible proportion d'une fibre cellulosique de renfort.
- 40 6. Elément (23) selon la revendication 5, dans lequel la fibre cellulosique est présente à une concentration d'environ 15 à 40 % en poids du noyau (21).
- 45 7. Elément (23) selon la revendication 5 ou la revendication 6, dans lequel la fibre cellulosique est une fibre de bois ayant une taille de particules d'environ 0,3 mm à 10 mm et un rapport longueur-diamètre d'environ 1 à 10.
8. Elément (23) selon la revendication 5 ou la revendication 6, dans lequel la fibre cellulosique est une fibre de bois ayant une longueur d'environ 0,3 mm à 3 mm, une largeur de 0,1 mm à 3 mm et un rapport longueur-diamètre d'environ 2 à 7.
- 45 9. Elément (23) selon l'une quelconque des revendications 1 à 8, dans lequel le thermodurci comprend une résine de polyester insaturée.
- 50 10. Blâment (23) selon l'une quelconque des revendications 1 à 9, dans lequel la fibre de la couche extérieure (20) comprend de la fibre de verre.
11. Elément (23) selon l'une quelconque des revendications 1 à 10, dans lequel il existe environ 20 à 40 % en poids de résine thermodurcie et environ 80 à 60 % en poids de fibre de verre dans la couche extérieure (20).
- 55 12. Procédé de fabrication d'un élément de structure composite pultrudé (23) ayant un noyau thermoplastique (21) et, lié au noyau (21), une couche extérieure (20) comprenant un thermodurci renforcé par des fibres, le procédé comprenant les étapes consistant à :

(a) extruder une composition thermoplastique, comprenant un polyvinyle et un renfort de fibres, à travers un poste de filière d'extrusion ayant un profil de section transversale non circulaire défini, pour former un extrudat à profil de noyau linéaire à une température élevée ;  
 5 (b) calibrer les dimensions de l'extrudat à profil de noyau et refroidir l'extrudat pour former un profil (7) de dimensions fixes ;  
 (c) former une couche extérieure non durcie comprenant des fibres et une résine thermodurcissable non durcie sur le profil refroidi de dimensions fixes ; et  
 10 (d) durcir la couche extérieure pour former un élément de structure (23) comprenant un noyau composite thermoplastique renforcé par des fibres et une couche extérieure thermodurcie renforcée par des fibres de renfort.

13. Procédé selon la revendication 12, dans lequel la couche extérieure (20) est appliquée sur le profil sous la forme d'un stratifiil bouclé.

14. Procédé selon la revendication 12 ou la revendication 13, dans lequel la couche extérieure (20) est associée à une résine non durcie avant l'application sur le profil.

15. Procédé selon l'une quelconque des revendications 12 à 14, dans lequel un dispositif de traction confère un mouvement linéaire au profil (7) à travers le procédé dans lequel le dispositif de traction (8) est en contact avec l'élément de structure (23) qui est durci.

16. Procédé selon la revendication 15, dans lequel les dispositifs de traction supplémentaires (17) sont installés après le profil de dimensions fixes.

17. Procédé selon l'une quelconque des revendications 12 à 16, dans lequel le noyau (21) comprend un extrudat linéaire ayant une section transversale carrée creuse ou rectangulaire creuse dont l'épaisseur de paroi est supérieure à 1 mm.

18. Procédé selon l'une quelconque des revendications 12 à 17, dans lequel la couche extérieure (20) couvre toute la surface du noyau (21).

19. Procédé selon l'une quelconque des revendications 12 à 18, dans lequel la couche extérieure (20) est placée sur le noyau (21) pour conférer un renfort dans une direction définie de contrainte appliquée.

20. Procédé selon l'une quelconque des revendications 12 à 19, dans lequel la noyau (21) comprend un composite thermoplastique comprenant une grande proportion de polychlorure de vinyle et une faible proportion d'une fibre cellulosique.

21. Procédé selon la revendication 20, dans lequel la fibre cellulosique est présente à une concentration d'environ 15 à 40 % en poids du noyau.

22. Procédé selon la revendication 20 ou la revendication 21, dans lequel la fibre cellulosique est une fibre de bois ayant une taille de particules d'environ 0,3 mm à 10 mm et un rapport longueur-diamètre d'environ 1 à 10.

23. Procédé selon la revendication 20 ou la revendication 21, dans lequel la fibre cellulosique est une fibre de bois ayant une longueur d'environ 0,3 mm à 3 mm, une largeur d'environ 0,01 mm à 3 mm et un rapport longueur-diamètre de 2 à 7.

24. Procédé selon l'une quelconque des revendications 12 à 23, dans lequel le thermodurci comprend une résine de polyester insaturée.

25. Procédé selon l'une quelconque des revendications 12 à 24, dans lequel la fibre de la couche extérieure (20) comprend de la fibre de verre.

26. Procédé selon l'une quelconque des revendications 12 à 25, dans lequel la couche extérieure (20) comprend environ 20 à 40 % en poids de résine thermodurcie et environ 80 à 60 % en poids de fibre de verre.

FIG. 1

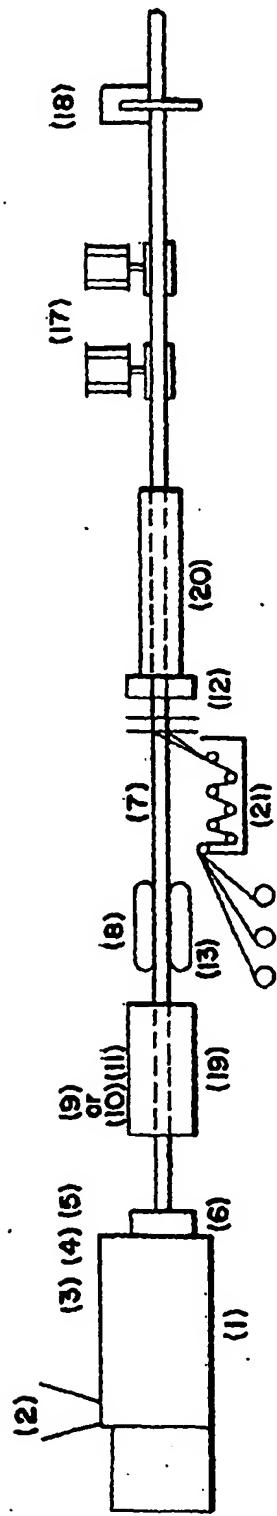


FIG.2

